SCIENCES IN THE HIGH SCHOOL[1]

I HOPE that my coming before you without a written address will not be considered by the Schoolmasters' Club as an act of discourtesy. Following the advice of the physician who suggested to a friend that he try his prescription upon the dog, I have tried this method upon the dog for some seventeen years, if I may so irreverently designate the body of students who have come under my instruction; and having thus tested it, I venture to hope that the mode of administration may be agreeable and the medicine itself not injurious.

I am to speak to you in somewhat more general terms than is indicated by the subject which I rather hastily sent to the secretary, "Observational Sciences in the High School," for I have more to say upon the general subject of science in high schools than I anticipated. Afterwards I shall consider specifically those sciences which I designate as observational.

I hope you have little expectation of anything novel upon this much discussed theme; if you have none, your expectations coincide with mine, for I feel that it will be practically impossible for me to say anything which in substance is really new. Yet, perhaps, we may find that when the kaleidoscope is turned by a strange hand, discrete thoughts will fall into some new combinations, and I may trust to your own bright wits for the reflection of these thoughts into symmetrical and coherent forms.

The query, "Shall science be taught in the high school or not," belongs to the realm of settled questions. It is scarcely debated; it is certainly no longer debatable. The immense strides which science has made in the past few decades, the tremendous impulse which it has given to all forms of human

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enterprise and industry, the new comforts which have been introduced into our lives through its help, have so directed popular attention to scientific development and have made scientific study so attractive, that the people who support the schools have demanded and are surely obtaining the teaching of sciences in them.

But the question which is still debatable, and must, I think, be carefully considered is, "What is the rightful place of science teaching in the high school?" At the very outset let me call your attention to the fact that in discussing this question extremely faulty comparisons are often made. When the time needed for adequate science teaching is under consideration, it has not infrequently happened that the teacher of Latin has complained that too much time was being allotted to the sciences; indeed, teachers of the classics are inclined to be rather jealous of the growing amount of time, as well as of the growing attention, devoted to these topics in the high-school curriculum. Have we not all observed that our friend the Latinist is apt to compare the amount of time assigned the sciences with the amount devoted to Latin?—forgetting that the rightful comparison is not between Latin and the sciences, but between Latin and some one science; or, if you please, between the sciences and languages as a whole. Let us make sure first, that we are comparing comparable branches of learning; then only shall we be able to decide justly the relative time to be accorded to science teaching. Lest I be misunderstood, I must allege that I am not decrying Latin and Greek; I have derived too much help from the training gained through their study to seek to diminish in any way the honor that rightfully belongs to them, and the important place to which they are entitled in our courses of instruction. I do not misprize their disciplinary value; I only exalt the discipline of science, which I think I may fairly say is equal to theirs in degree, although different in kind. If our friends who are interested in the language studies are saying that time, long and continuous, is indispensable to obtaining this discipline from Latin or Greek, I am saying that

time, long and continuous, not in the sciences, but in *some one science* is equally indispensable to the acquisition of the discipline which these sciences undoubtedly yield to one so pursuing them.

In order to determine the rightful place which science teaching should have, one must first examine the very numerous claimants for place in the high-school course. Notice what has been done in the admission of science to high schools; what great diversity there has been in the different schools; what a great number of sciences have been taught at one time or another in the schools. You will hardly fail to be surprised if you examine the courses. I enumerate only the important ones which have commonly found a place: physics, chemistry, botany, zoölogy, physical geography, human physiology, psychology, astronomy, and geology. No such a list of sciences as that can be taught, certainly they cannot be properly taught, in any single school. Yet I was employed in a city high school which had *seven* of these in its curriculum, and I was not permitted to reduce them below *five!* Indeed, we find almost as great a variation in the number of sciences admitted to the high school in one place or another, as in the choice of subjects.

What has determined this great variation in the choice, number, and character of science subjects? I imagine the course of many schools has been developed in very much the same way that Topsy developed, it "des growed." Without any serious consideration, this topic has been introduced, and then that, until by and by an unsymmetrical body, with irregularly disposed branches, without any particular relation to each other, has resulted. When we find a misshapen organic form in the plant kingdom, we are sure that nothing will help it so much as judicious pruning. That is equally true of the curricula of many schools. A man with judgment, empowered to lop off those things which are easily and rightfully dispensed with, is greatly needed in most high schools.

But even if the choice of the subjects has been carefully made, the selection is liable to be based upon what is called pedagogical adaptation; that is upon the idea that such and

such topics are suitable for pupils at the age or stage of development ordinarily met at the time at which this subject is to be taught. I fear I shall speak heresy if I say that this notion of "pedagogical adaptation" ought not to constitute a chief factor in the choice. But the orthodoxy of today was the heresy of yesterday. Pedagogical adaptation is often an expression not for an actual *thing*, not for that which exists. When one says that such and such a science is "adapted" to fourth-year pupils, it merely means that his idea of the part of a science to be presented and the manner of presenting it is adapted to seniors in the high school rather than to freshmen. But there is a freshman aspect of every subject and a senior aspect. They are not the same; and he is a poor excuse for a teacher who would present the same material in the same way to pupils of such different powers. Instead, therefore, of making some one's conception of a science the basis for including it or excluding it from the high-school course, of teaching it in this year or that, choice of it should be determined by an entirely different criterion; *then* demand that the subject so entered in the course be presented to the pupils in a pedagogically correct fashion. In other words, I should adapt the teaching of a subject to the pupil, and not try too strenously to adapt the subject to the pupil. That may sound a little like the difference between "tweedledum" and "tweedledee," but I think it is really important.

The considerations which actually determine the choice of subjects are not simple and unrelated; they are composite, and interlocked in such a fashion that it is extremely difficult to separate them and consider their individual value; and even if the best choice is made, it is possible that it will be rendered entirely futile by incompetency on the part of the teacher. And therein we meet what is universally conceded to be the crucial point in the whole matter. It is useless to insist to you who are devoting your time and attention to teaching that the teacher's relation to the success of the school is an absolutely vital one. We all believe it after a fashion; yet I wonder if we believe

it so as to act upon it? How many of us at one time or other have been — we are tempted to say forced, yet if we tell ourselves the truth we cannot quite say that — put into a false position by having assigned to us a study which we knew perfectly well that we were not competent to present to the pupils? How many of us — and I am talking to myself now as much as to you — have gotten money under false pretenses in that way? It is difficult, especially when one's bread and butter may depend upon it, to say to a principal or superintendent, "I cannot teach that subject as it ought to be taught;" and yet common honesty, I believe, requires us to decline to attempt teaching for which we know we have not adequate preparation. How difficult it is for us to secure real success! How many causes of failure are there on the part of the teacher! To all these inadequate preparation is fundamental and of it I must speak again later.

But given adequate preparation, lack of adaptability is the chief source of failure. The teacher who tries to introduce into the high school a miniature of the course which he has been through in the college, what a misfit he is! Better would it be had he never seen the college than to force upon the high school this imitation. The teacher who cannot adapt himself to the needs of his pupils, who cannot put himself into their places and see their difficulties, is sure to be a failure. Adequate preparation may, indeed, be nullified by inadequate adaptability.

When we desire to reach a definite object in any line of action, we are accustomed to consider first, what is the goal to which we desire to attain; we ask, what is the end sought, and then rationally endeavor to adapt our means to that end. Before, therefore, any choice is made in regard to what subjects shall be taught in the high school, we must ask ourselves just what we intend to accomplish by science teaching in the high school.

As I see it there are mainly two things to be secured by such teaching; two things, I mean, in the way of discipline, for I leave out of consideration for the present the question of the informational value of any subject. I acknowledge that every

science has important information to impart to its students. I grant the full value, practically and theoretically, of such information. But I look upon science teaching as the Latinist upon his teaching of Latin, not as of value for the information in regard to the Romans and their enemies, which the student may derive from it, nor for the historical facts which he may get incidentally from his reading of Livy or Tacitus, but as *of value for the mental discipline which it imparts.*

The first of the two objects which is to be secured is the cultivation of the power of accurate observation, and the training in the method of deducing general principles from particular facts. That, it seems to me, is the primary end to be attained; and it is fundamental because our method of education, far too greatly, I take it, has been directed to dwarfing the power of observation. True, we are beginning to remedy that by the introduction of observational sciences in the lower grades; but we have been systematically developing the memory at the expense of the power of observation.

The second thing which is to be done by science teaching is to develop the capacity for determining exact data and deriving therefrom accurate results. To express these two objects in other terms, I may say that we need to train the powers of the student by methods which may be called on the one hand *qualitative* and on the other *quantitative*. Or, to put it in another way, one object is the cultivation of the *ocular accuracy*, the other is the cultivation of *instrumental accuracy;* while from the reasoning involved in both methods the outcome is *logical accuracy*.

Now these two disciplines may be secured from any single science, and whether one or both is secured depends upon the way in which that science is presented. For example, it is perfectly possible to set a student to the examination of the living plant, and ask him to determine with accuracy the structure of every part of that plant. Agassiz is said to have set his students at work upon a fish, and when they had reported the next day the points which they had seen he set them at work

upon the same fish; and so on and on for days until they had finally seen all that there was to be seen about the object which he had given them. For the beginner this is monstrous misuse of time, but it is a famous illustration of the way in which students were finally trained to discover things which they were unable to see at first. In some such way, with the guidance which he needs, the student may have his eyes sharpened until he is capable of correctly observing the peculiarities of plants. But if in the physiological laboratory we set him at work with balances, with electrical apparatus, with gas apparatus, to determine the exact changes which go on in that plant in the course of its life history; if we set him to find out how much carbon dioxide it breathes out in the course of twenty-four hours, and how much oxygen it consumes in that time, we can develop an ability to determine exact data and to derive from those data exact results. From the two methods we secure two quite different disciplines; the one is qualitative, the other quantitative. It is the same in physics. We may set the student at work in qualitative physics, and we get one kind of training; if we set him to determine the physical quantities, we get another.

But certain sciences are better adapted than others to secure one or other of these results, especially if we take into consideration the way in which these sciences can be presented in the high school. Training in qualitative work, *i. e.*, along observational lines, can be given better by the use of the biological sciences than any others. Training in quantitative work, *i. e.*, along instrumental lines, can be given better and more readily by the use of the molecular sciences. By these considerations, therefore, we have our choice narrowed on the one hand to botany and zoölogy, and on the other to physics and chemistry. Understand, this is purely from the view-point of discipline.

Having so far limited the choice of sciences for the high school, what other factors are to be considered? Our choice is further restricted by the too frequent changes of teachers and the differences in their preparation to teach particular subjects.

In order to overcome this difficulty, in part at least, I advocate great flexibility in the curriculum of the high school. Suppose this year we have in the school a teacher who is well trained in botany. Unfortunately, next year we lose that teacher, and are obliged to secure one who is not well trained in botany but has had thorough preparation in zoölogy. The curriculum calls for botany; the teacher is trained to teach zoölogy. What shall we do? By all means let him teach zoölogy, and do not force him to do poorly what he is really not prepared to do at all. Let the curriculum be flexible enough so that we may have botany one year and zoölogy the next, if necessary to secure good teaching; and I should say the same thing in regard to physics and chemistry. I am quite aware that I shall be answered, in thought if not in words, that, in the first place, the university at the head of the school system of the state requires botany for entrance, and the high school has no option; and, in the second place, that the thing is not practicable. To the first objection I answer that no university will insist on poor botany when it can get good zoölogy as an equivalent; and to the second, that it *is* thoroughly practicable, and has been done in actual school administration.

Our choice between the biological sciences is further limited by the character of material required. It is easier to obtain, to preserve, and to use the material upon which botany depends than that upon which zoölogy depends; therefore, other things being equal, I should say botany is better adapted to the high school. In the same way our choice between physics and chemistry is properly influenced by the cost of equipment and maintenance. In many cases this is financially of dominant importance. I should say, other things being equal, that physics is the better of the two for high-school purposes; primarily, because it is better adapted to quantitative presentation than chemistry, and also because its equipment and maintenance is less expensive.

Since there must be a choice of subjects, for the reasons given I say that *botany and physics should be made the backbone of*

the science course in the high school. But what of other sciences, human physiology, astronomy, etc.? These stand, I believe, upon a wholly different basis. They may be considered as desirable only for their informational value, and this is certainly very small in most cases. So I care very little about the informational sciences of the high school; what they are and how much shall be given of them must be determined by the available time of the student.

Ninety per cent. of the high-school students, it is often alleged, do not go to college; they do not get any information except that which comes from the high school. Shall we not give them, then, this information? Passing by the false percentage, upon the same ground we ought to give them a great deal more information. Do you not see that this argument proceeds upon the tacit assumption that education is wholly or chiefly a function of the schools?—an assumption as common as it is false. But, of course, pupils cannot get from the schools all the facts that might be useful to them if applied. What? Shall we not teach human physiology (by which name we designate a sort of hodgepodge of human anatomy and hygiene with barely enough real physiology to salt it) in order that the high-school pupils may know how to live? They *must* know how to care for their bodies! But they certainly derive very little advantage from this study miscalled physiology. It is not the hygiene of the high school, but the hygiene of the home and of the doctor that mainly influences our children. And even did they have to rely wholly upon the school, I should rather have a man who had been thoroughly trained in one or two sciences set to consider how he should live, than a man without such training who had been taught all the hygiene that is contained in the elementary text-books. I say this because such a man would be able to carry out an experiment and discriminate its factors with some exactness. Think you that we should have the immense sale of patent medicines if people knew how to experiment? What does the average man do when he experiments with a patent medicine? He performs an experiment in

which he knows and considers only one of the factors, while there may be forty others of which he has taken not the slightest account. So he attributes his recovery to the power of the medicine, the one factor that he does know. Do you suppose a man who had been properly trained in a physical laboratory would reason in that fashion? He ought to be too wise to call such foolishness an experiment.

A theme which has been the subject of endless discussion is the order in which the subjects chosen are to be presented. Each teacher is inclined to think that all other subjects are merely the foundation upon which his is to rest as the superstructure, and therefore he wants all other studies to precede his in the curriculum. The teacher of physics is sure he cannot get along without algebra and trigonometry. The teacher of botany would feel exceedingly happy if he could only have physics and chemistry to precede his work, and the teacher of geology thinks there is no geology for the pupil unless he has studied physics and chemistry and biology. Much of the discussion has based itself upon what is called the logical relation of subjects. But it seems to me that the logical relation of subjects is unimportant for the arrangement of studies in the high school, because every subject can be presented to the pupil in that aspect in which it is suitable to his powers, and must be so adapted if it is properly taught. If botany is put in the first year, the suitable aspect of botany can be presented to the first-year pupil; if it comes in the fourth year, it can be presented to the senior; but he would be a foolish teacher who in either content or method taught both in the same way. Is it not true, therefore, that we may let this whole matter of precedence of subjects adjust itself to the necessities of the school or the teachers, and not feel any particular subject defrauded of proper place because it does not come after some other? This is not saying that there is not a logical relation of subjects considered in their fullness; but we do not present subjects in their fullness in the high school.

Keeping in mind the conclusion that physics and botany

should constitute the backbone of the science work in the high school, I ask next, What should be the relation between laboratory work and the text? Naturally this must depend, in part at least, upon the time devoted to each. If you ask me how much time I would have, I say, *at least* a year in physics, and *at least* a year in botany; if possible, a year and a half of each, with daily work, for which the laboratory periods shall be double the usual recitation period, and therefore not less than ninety minutes. Less than a full year for each science deprives it largely of disciplinary value. If any think I ask too much, I may remind them of the demand that Latin shall be given for four years. What would be said if the botanist were as greedy?

At present we teachers of botany are busily engaged in insisting that there shall be laboratory work, and a great deal of it, because we feel that that is the first necessity of right presentation of the subject; but with this insistence, I believe we do not forget that there should be a coördination of the facts gained in the laboratory with the general principles illustrated by those facts; that we should use the facts of the laboratory to illustrate a text which deals with the wider fields. I do not believe the lecture adapted to pupils in the high school, and should not use it with elementary classes in the college when it is possible to obtain a text-book. Unfortunately that is not always easy to do; yet even a poor text-book is better than none, for the teacher who knows its faults may more readily correct them than undertake to cover the ground in lectures. But let us not forget for a moment that no teacher of botany advocates the use of the text-book except as a supplement. A book used in any other way is misused. Let it be understood that I strenuously insist upon the necessity of laboratory work in sciences.

The failure to coördinate laboratory work and general principles nullifies discipline. I have questioned pupils in schools, who were painstaking users of the compound microscope day after day, to find out if they knew what they were seeing with the compound microscope. They had no conception of the

plants they were studying; but they had accumulated a mere mass of facts, more or less isolated and unimportant, which they might remember a few weeks and then forget forever. Do you not see what this is? It is merely a repetition of memory training. It is the old wolf of memory masquerading in the sheep's clothing of observation. Correlate the laboratory work; make it illustrate general principles; enable the pupil by its means to overlook the wider fields.

There is another danger from over-insistence upon laboratory work, and that is the danger of forming a habit of superficial study. I have seen schools in which students were rushed from one plant to another, skimming the surface features without getting hold of significant structures, until they had become so confirmed in the habit of casual study that the discipline of laboratory work was largely lost. This danger is especially great in any qualitative work; and teachers are led into it from a desire, sometimes almost unrecognized, to have pupils cover as much ground as possible. Let us rather strive to intensify the laboratory work; it is not necessary to present all the science in a twelve-month. Far better that work should be so arranged so as to hit hard and often the principal facts.

I have already spoken of another danger, that which arises from the imitation of college courses in the high school by teachers without adaptability or with a strong habit of mimicry. Such courses are positively harmful and leave pupils puzzled and discouraged. They need prompt aid if they are to escape mental asphyxiation.

Let us now turn from these general principles to a more specific discussion of the teaching of botany.

I ask first, What has the high school done with botany in the past? It has done very much what the colleges and universities have done in the past; unfortunately it tends to continue the old ways a little longer. I think I may fairly characterize the teaching which I condemn as the presentation of a botany butt end first. We have gone at it like the militia dealing with the unruly mob, who are ordered to "reverse arms

and give 'em the butt;" the pupils are stunned by it but not penetrated, and hundreds have received such a distaste for the whole subject that as soon as they have "had botany" (with much the same disgust as they felt when they "had" the measles), they are glad to think there is to be never an opportunity for them to have it again. Curiously enough, this is the history of the teaching of every subject. I scarcely think of any exception. When we have endeavored to present what we falsely call the elements of a subject, we have given to the student the philosophical concepts which are reached after long study. Have not text-books reflected this method in setting before the student a mass of definitions? How many text-books on physics are there on whose first page there is not a definition of matter and force and molecules? When we present these subjects in that way we are simply making it impossible for the student to grasp them. How many classes have been rushed through definitions of a leaf and of its forms, the flower and the variation in its form, the stamens, pistils, and all that sort of thing, in order that they might get ready to study plants? Again and again have teachers said to me, "We go over these definitions rapidly in the first six weeks of the spring term so as to get ready for the spring flowers." Happily that day is passing away, and we begin to see that the study of classification is a study for the university graduate. But people object to it—even teachers. Someone says the child ought to know the names of plants and flowers and the trees with which he meets. When a friend comes into the house, do you say to the child, "Now, Harry, here is a new specimen, and I want you to observe very closely the form of his body, the color of his eyes and hair, the ornaments he wears, and make a complete set of anthropological measurements, and write them down on this piece of paper; when you have done that I will give you a genealogical table by which you may ascertain his name." Absurd? Yes; but is it more absurd than the way we treat him about our plant friends? What you do with your friend is to give the child an introduc

tion to him. You say, "Harry, I want you to know Mr. Smith." Why should we not treat him in the same way in regard to plants? Probably Harry will not know Mr. Smith the next time he sees him, and he may not know the white oak the next time he sees it. "Harry, you remember you met Mr. Smith the other day? This is he." "Harry, you remember you saw the white oak the other day? Look at it and see if you know it." When we teach the child about birds we do not set him to measure the bill of the robin, or the distance between the eyes, or the length of the primaries; but set him to see how the robin behaves, how he lives and moves and has his being. Now, can we not answer those who object to the dropping of the work miscalled "analysis"?—the parents who say to the teacher, "You do not know how to teach botany if you cannot teach my son as I was taught it; I want him to study it as I did." Such objections are actually made, and have been related to me again and again by teachers. Rather than follow the old paths which led a few into pleasant fields while they repelled the many, let us devote attention to what a plant *is* and what it can *do*.

How can we best teach the pupil what the plant is and what it can do? By letting him observe what plants are; not merely one kind of plant, but representatives of the four or five great groups, the algæ, fungi, mosses, ferns, and seed plants. I see no objection to devoting the greater part of the time to the seed plants, because we must recognize that this is the largest group and the most important and demands the consideration of the young student more than the others; but I would not have him ignorant of the other groups. We can teach him what a plant can do by qualitative experiments, and especially those which involve a study of the relation of plants to the living world, the animals and plants about it, and to the inorganic world, the soil and water and air by which it is surrounded. Every course in botany should include physiology, to be introduced just as soon as students have acquired an adequate knowledge of the structure of plants and the plans upon which they are built.

In planning any course there are innumerable details which

it is absolutely indispensable for each teacher to work out for himself. Only a few general statements can be made, and these largely by way of emphasis of what was said in the course of the afternoon discussion, for I am traversing ground with which you are familiar.

1. First of all, because it is fundamental, I cannot refrain from referring again to that old matter of an adequate preparation. The teacher who has studied botany for twenty weeks cannot possibly teach botany for twelve weeks to high-school pupils as it ought to be taught; it is simply out of the question; not even a genius can do that. In fact there is necessary for the teacher of a subject who must address himself to primary students a much more extensive acquaintance with the subject relatively to the advancement of his pupils than is required of the university teacher. No one can make a subject simple who does not know it from bottom to top as compared with his pupils, and I believe that there is even greater need in the high school for well-trained teachers than there is in the university.

2. The laboratory periods *must* be at least twice as long as the recitation periods. I know all the objections that are brought up against that: we cannot get time; we cannot possibly give that double time; it interferes with the whole schedule. This is because the schedule was constructed without any reference to those double periods. It *is* possible, provided there is adequate help, and that can only be secured when it is observed to be indispensable.

3. It is absolutely necessary that the teacher who is conducting the laboratory shall have at least the period before the laboratory work to get ready for it. No teacher can leave a class in algebra or history and immediately take a class in botany and do it justice; he cannot teach it as it ought to be taught without time for preparation of materials and directions. Instead of thinking such time clear gain to the teacher, the superintendent ought to be aware that it is clear gain to the pupil and the busiest time in the teacher's day.

4. It goes without saying nowadays that there needs to be a

laboratory room, properly equipped. This demand is not visionary even for the smallest school. I know the small high school and its limitations in the way of time, teachers, apparatus, and room. I know all these can be overcome by persistence and energy.

And when you have overcome the present difficulties will the university cease to create more? Will it ever be satisfied? Never; never! You need not expect the time ever to come when the university will cease saying to the high school, come up higher. It may not continue to call for *more* work; it should never cease to demand *better* work. Why, indeed, should it? The university and the high school are parts of one system. With the state university standing at the head, the public-school system is as much an organic whole as the human body. When the head ceases to say to the hands, "do thus and so," there is no evidence of maturity, but of death. So there will always be these demands from the university, because the university occupies a vantage point from which it sees clearly opportunities for its own improvement and feels it necessary for the secondary schools to grow with it.

Apart, we can do nothing; we must work together in this common cause, for this glorious aim, which is ultimately our country's good.

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